NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 1114

EVALUATION OF A NEW PRINTING OF PSEUDOISOCHROMATIC PLATES

by

S. M. Luria and David F. Neri

Defense Medical Standardization Board Task

Released by:

C. A. HARVEY, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

28 April 1988

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SUMMARY PAGE

THE PROBLEM:

To determine if a new printing of the pseudoisochromatic color vision test plates was erroneously failing individuals with normal color vision.

THE FINDINGS:

Spectroradiometric measurements of the colors in the new plates were almost identical to those in the old plates. There were no failing scores for 20 color normal individuals tested with the new plates. It was evident, however, that the quality control of the new printing was less precise than that of the old plates.

APPLICATION:

The new color vision test plates are satisfactory, and their continued use is justified.

ADMINISTRATIVE INFORMATION

This investigation was requested by CDR Uldis A. Delviks, MSC, USN, Chief of Opthalmic and Optical Laboratory Instruments and Supplies, Defense Medical Standardization Board, Ft. Detrick, MD. This report was submitted for review 13 April 1988, approved for publication on 28 April 1988, and has been designated as NSMRL Report No. 1114.

Abstract

A new printing of pseudoisochromatic plates was compared with the old printing in three ways to determine if individuals with normal color vision erroneously failed the new version. Spectroradiometric measurements of the colors were compared, 20 color normal subjects were tested, and the spatial arrangements of the dots comprising the plates were examined. There was no evidence that the new plates failed color normals, despite the fact that the quality control of the new printing was clearly less precise than that of the old plates.

Pseudoisochromatic Plates are colored figures used for rapid and easy evaluation of color vision. They are based on the fact that color-defective individuals typically confuse only certain colors. These fall along clearly defined lines on colorimetric charts. Two colors on such a "confusion line" which a color normal can easily differentiate may appear identical to a color defective. On the other hand, the same color presented at two different contrasts may be considered to be the same by a color-normal but perceived as different colors by a color-defective (Birch, et al., 1979).

Pseudoisochromatic plates utilize these facts. Spots of color in various sizes and contrasts are printed to form some design, often a numeral. The numeral may, for example, be composed of one group of colors while the background is composed of other colors which are on the same confusion lines. The color normal will see the color differences and perceive the numeral; the color defective will see a random pattern of colored dots. The plate may also have another numeral printed in the same colors as the background but at a different contrast. The color normal will tend to disregard this because it is the same color as the background, but the color defective will see the difference in contrast and report the second numeral.

It is clear that considerable quality control must be exercised in the printing of such plates. Recently a new edition of the American Optical Co. plates was brought out by the Richmond Products Company. Shortly thereafter, the Defense Medical Standardization Board received complaints that a set of the new plates might be defective (Delviks, 1987). It was reported that color normals were failing to perceive the figures on four of the 14 plates. Although more than four errors were required to fail the test -- and in that sense the color normals were still being passed -- the staff administering the test believed that most color normals should not be having this difficulty. The Naval Submarine Medical Research Laboratory was asked to evaluate the questionable set of plates.

METHOD

To determine whether or not the new set of plates is defective, we carried out three types of comparisons with other sets of the same plates by the previous printer. We tested subjects known to be color normal, we made spectroradiometric measurements of the printed colors, and we compared the geometry of the construction of the plates: that is, the number and placement of the dots comprising the numerals on the plates, and how satisfactory the resulting shape of the numerals was.

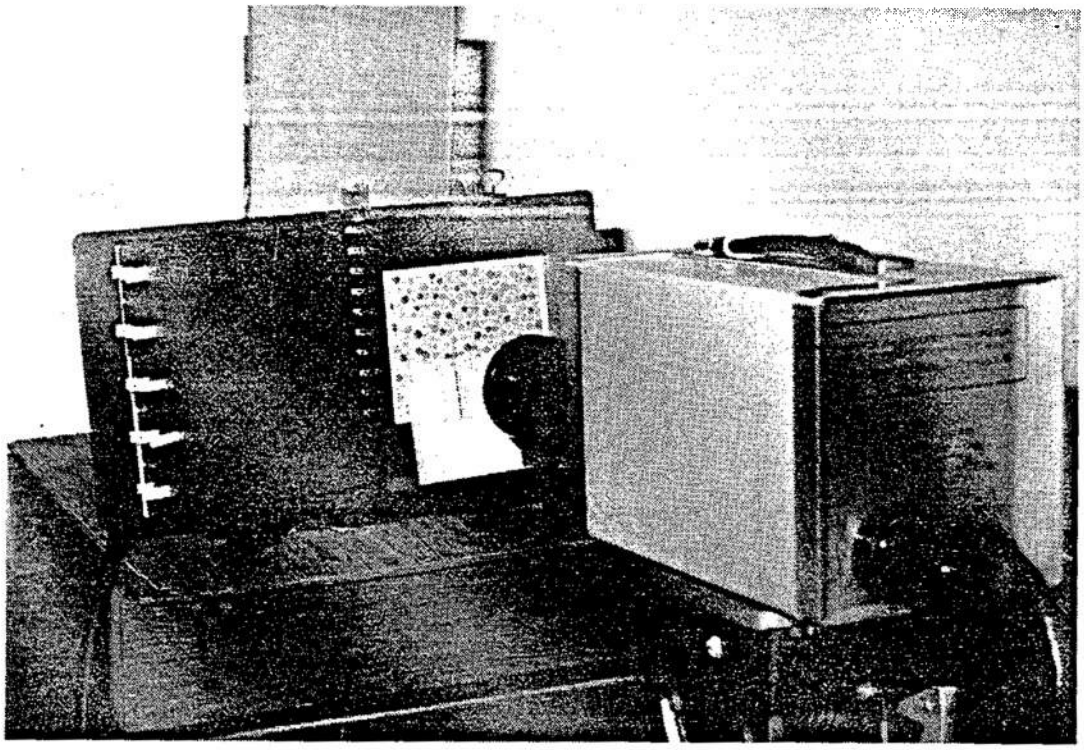
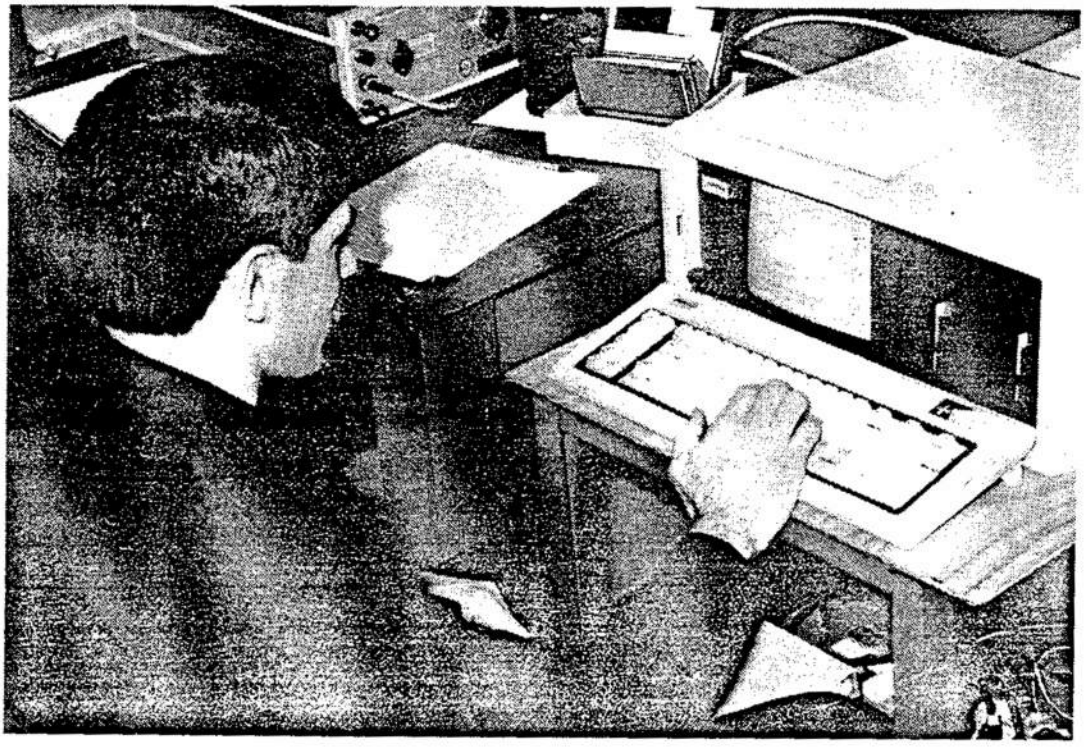


Figure 1. (a) The spectroradiometer measuring one dot. The test booklet is on an easel held at a set distance from the Macbeth lamp just outside the picture. (b) The Compaq computer displaying the spectral curve of the color and other information.



Subjects

The subjects were staff members of the laboratory who volunteered to participate. All had been tested before, and their color vision status was known. Twenty were color normal, one had a slight color vision defect due to a cataract operation, and three were deuteranopic dichromats.

Apparatus

Three sets of plates were used. One was the set recently produced by Richmond Products which was suspected of being defective; the second was another set of plates from Richmond Products which presumably had elicited no complaints; the third was the identical set of plates marketed by the American Optical Co. and printed in 1976 by the Beck Engraving Co.

The plates were illuminated by the filtered tungsten light of a MacBeth Easel Lamp which emits the proper CIE Illuminant "C" light for such testing (Farnsworth, 1951; Birch et al., 1979, p. 101). The testing was done in an otherwise completely dark room with the plates at the prescribed distance of about 24 inches from the subject's eyes.

The spectral curves and luminances of the colors were measured with a Photo Research 703A Spectroradiometer in conjunction with a Compaq micro-computer (Figure 1).

Procedure

Color vision testing. The three sets of plates were administered to each subject in a different random order, and the plates in each set were presented in different orders to the subjects. Both incorrect responses and hesitation in reading the plates were recorded. No feedback was given to the subjects.

Spectroradiometry. Measurements were made of at least two identical spots making up the numeral and at least two identical spots in the background on each plate in each set. However, all the colors making up both the numerals and the backgrounds were measured on the four plates which produced the most errors by the color normals (Plates 9-12), as well as two of the plates which the color normals judged to give the least difficulty (Plates 5 and 14), and two plates which they judged to be of intermediate difficulty (Plates 6 and 15).

Examination of dot geometry. Finally, the dots comprising the numerals on the plates were isolated in order to assess the quality of their spatial arrangement and the ease of reading the numerals independent of any color vision requirement.

TABLE 1. Total number of errors and long response-times made on each plate in the original Beck set, the new printing, and the questionable set by the 20 color-normals.

	ERRORS			HESITANT RESPONSES		
Plate	BECK	NEW	QUES	BECK	NEW	QUES
2	0	0	0	0	0	0
3	0	0	0	0	0	1
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	1	1	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	6	6	4	2	3	6
10	10	7	8	2	3	6
11	9	11	6	2	1	3
12	0	5	5	1	2	3
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	1	1	1	0	1	0
Total	25	29	23	7	10	19

RESULTS

Table 1 compares the subjects' results with each of the three sets of plates. It shows the total number of errors and the number of hesitant responses for each of the 14 plates by the 20 color-normals. Every color normal attained a passing score on each of the three sets of plates. The subject with the slight color deficiency had a total of five errors (one more than the passing score) on the original set of plates and one set of the Richmond plates, but passed the Richmond set which was suspected of being defective. The results of the three deuteranopes are not given, since, as expected, they failed to read most of the plates in all three sets.

Table 1 shows that only on plate 12 was there a noticeable degradation in the performance of the subjects with the two new printings; the 20 color normals made no errors on this plate with the old set, but they made a total of five errors with each of the two new sets. It may be noted, however, that they also hesitated more with Plates 9 and 10 of the questionable set, although they made no more errors.

Table 2 gives the spectroradiometric measurements for Plates 9 to 12, and 15. Sample measurements for the numerals and backgrounds of Plates 9 and 10 are given, but the measurements for all the colors for Plates 11, 12, and 15 are given. This shows how the corresponding dots on each set of plates compare in terms of chromaticity and lightness for the four most difficult plates and one of intermediate difficulty. These results are completely representative of those from the other plates. The dominant wavelengths and saturations of the colors are printed reasonably reliably for every color in every plate with only one exception. One of the colors in the numeral on plate 12 of the questionable set (chromaticity of .37, .44) was appreciably different from the color in the other two sets. Otherwise, the chromaticities of each color are virtually identical for the three sets.

The biggest differences between the sets are in the luminances of the colors. A given color may be considerably brighter in one set than another, although it is clearly the same color.

TABLE 2. Spectroradiometric measurements.

	x	y	Dom. WL (NM)	Sat.	Lum(ftL)@
Plate 9 numeral-					
Beck	.38	.37	581	.25	1.62
New	.38	.37	581	.25	1.88
Ques	.38	.37	580	.25	1.95
Beck	.33	.36	554	.10	1.67
New	.34	.37	562	.13	1.50
Ques	.38	.37	561	.12	1.75
Plate 9 Background-					
Beck	.34	.37	558	.11	2.18
New	.34	.37	563	.13	2.24
Ques	.34	.37	564	.14	2.26
Beck	.37	.39	573	.29	4.41
New	.38	.41	572	.37	2.94
Ques	.38	.41	574	.37	3.53

	x	y	Dom. WL (NM)	Sat.	Lum(fL)
Plate 10 Numeral-					
Beck	.37	.38	577	.26	3.05
New	.37	.39	574	.28	3.77
Ques	.37	.38	576	.26	4.47
Beck	.38	.38	579	.27	2.51
New	.38	.37	580	.26	1.52
Ques	.38	.37	580	.26	1.66
Plate 10 Background-					
Beck	.37	.40	573	.30	2.93
New	.38	.41	572	.37	2.41
Ques	.38	.41	572	.38	2.65
Beck	.36	.38	571	.22	3.09
New	.35	.38	570	.20	2.11
Ques	.35	.38	570	.20	2.36

TABLE 2 (Continued)

	x	y	Dom. WL (NM)	Sat.	Lum(fL)
PLATE 11 Numeral-					
Beck	.38	.37	582	.25	1.18
New	.39	.38	579	.32	3.02
Ques	.38	.38	578	.31	1.02
Beck	.37	.38	572	.25	2.62
New	.37	.39	572	.28	2,44
Ques	.37	.39	572	.27	2.46
Beck	.36	.38	572	.23	4.61
New	.36	.38	572	.24	3.46
Ques	.36	.38	572	.23	3.59
Beck	.38	.37	581	.26	3.63
New	.38	.37	580	.25	3.08
Ques	.38	.37	581	.25	2.84
PLATE 11 Background					
Beck	.33	.37	554	.11	1.62
New	.34	.37	557	.12	1.20
Ques	.34	.37	557	.13	1.47
Beck	.37	.41	571	.34	1.65
New	.37	.43	569	.41	1.21
Ques	.37	.41	570	.35	1.69
Beck	.37	.40	574	.33	4.22
New	.38	.41	574	.35	3.84
Ques	.38	.41	574	.36	3.52

TABLE 2 (Continued)

	x	y	Dom. WL (NM)	Sat.	Lum (fL)
PLATE 12 Numeral-					
Beck	.38	.37	582	.26	2.19
New	.39	.38	580	.32	1.67
Ques	.37	.44	567	.42	1.11
Beck	.37	.38	578	.25	4.75
New	.37	.39	574	.28	4.50
Ques	.37	.38	575	.27	4.82
Beck	.37	.38	575	.24	6.54
New	.37	.38	574	.27	5.85
Ques	.37	.39	574	.28	5.63
Beck	.37	.38	573	.24	4.39
New	.36	.38	572	.24	3.75
Ques	.36	.38	574	.23	3.10
PLATE 12 Background-					
Beck	.34	.37	558	.12	2.54
New	.34	.37	567	.14	3.36
Ques	.34	.37	561	.13	2.48
Beck	.38	.40	572	.34	5.01
New	.38	.41	573	.38	3.79
Ques	.38	.41	572	.37	4.03
Beck	.34	.37	558	.11	2.39
New	.34	.36	562	.13	1.84
Ques	.34	.37	561	.12	1.62

TABLE 2 (Continued)

PLATE 15 Numeral-

	x	y	Dom. WL (NM)	Sat.	Lum(fL)
Beck	.43	.40	584	.49	2.74
New	.42	.39	585	.43	2.84
Ques	.43	.39	586	.46	2.60
Beck	.42	.38	588	.40	2.00
New	.43	.38	588	.44	1.88
Ques	.42	.38	585	.40	2.17
Beck	.43	.39	586	.46	2.79
New	.43	.39	587	.43	2.76
Ques	.43	.39	588	.46	2.14

PLATE 15 Background-

Beck	.41	.39	580	.40	1.77
New	.40	.39	580	.36	1.72
Ques	.39	.38	580	.33	1.91
Beck	.39	.40	579	.35	3.68
New	.39	.39	579	.34	3.47
Ques	.39	.39	578	.32	3.54
Beck	.41	.41	578	.46	5.26
New	.41	.41	578	.45	4.27
Ques	.41	.41	578	.44	4.35
Beck	.40	.40	577	.40	4.77
New	.39	.40	577	.36	4.46
Ques	.39	.40	577	.35	4.22

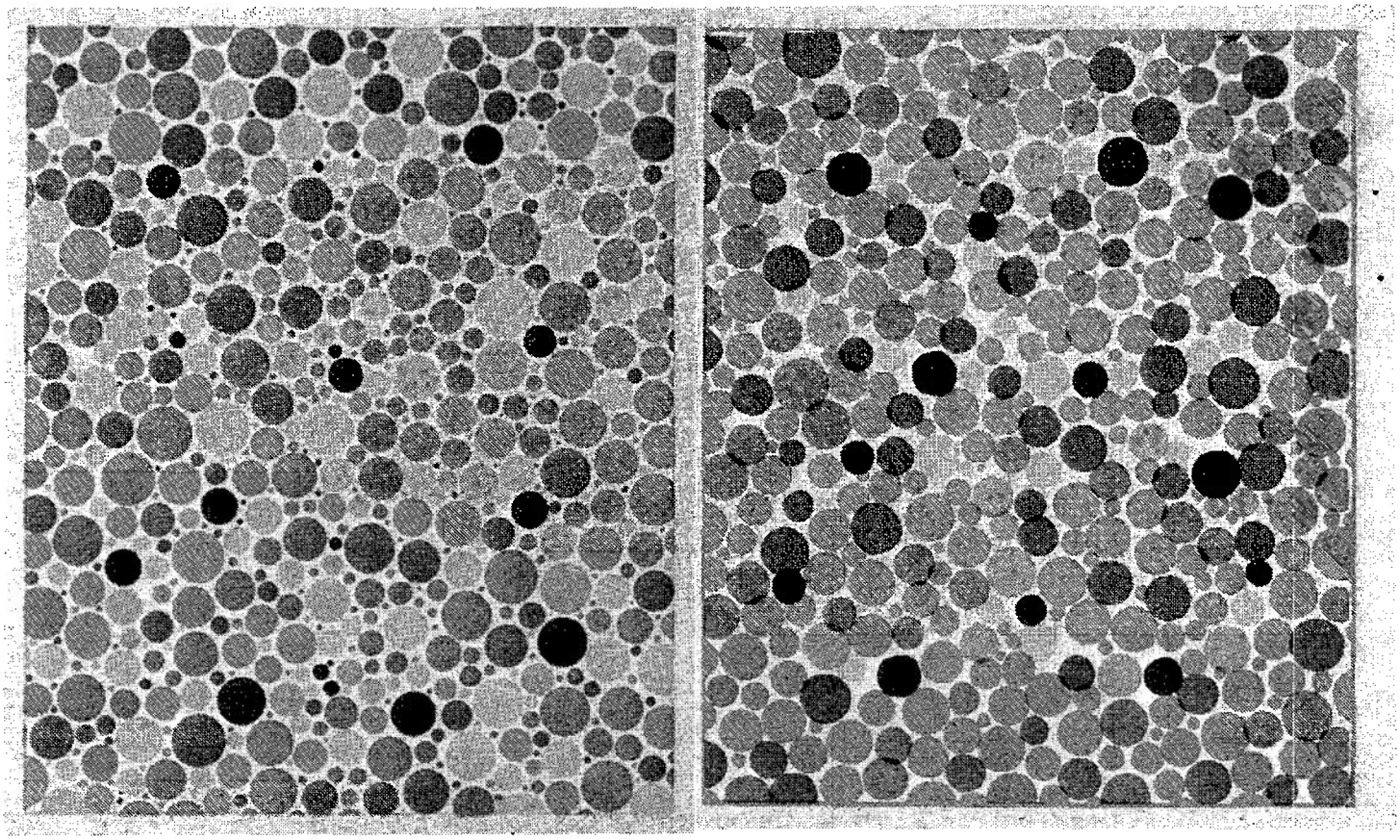


Figure 2. A photograph of a plate from the original set (left) and the corresponding plate from the new Richmond Products set of plates. The elimination of the small "filler" dots and the less precise placement of the dots is evident.

Finally, the number and placement of the dots comprising the numerals and backgrounds on the plates were examined. Figure 2 shows a plate from the original set and the same plate from the new Richmond printing. Two differences are quite apparent even in this black-and-white reproduction. First, the separation of the dots is much more carefully controlled in the older set of plates. None of the dots overlaps. In the new printings, there is considerable overlap of the dots, resulting in very small regions of unintended colors being introduced.

Second, the original plates had many small dots which have been eliminated in the newer printing. Although they probably have no bearing on color discrimination, they appear sometimes to improve the sharpness and clarity of the outline -- the geometry, if you will -- of the numerals which the subject is trying to discern. Many of the subjects complained that their ability to report the correct numeral on a plate often depended on the geometry of the numeral rather than on the color. Figure 3a gives an example of a numeral whose outline is sharp and whose shape is unambiguous. If the color difference can be seen, the numeral will be read easily. Figures 3b and 3c show numerals which are read only with some difficulty. The "2" in Figure 3b has begun to resemble a "9", and a "7" is typically never seen in such a curved configuration. Even a color-normal observer wonders if he is seeing "27" or "perhaps "99" in Figure 3b, and if it is a "9" or an "8" in Figure 3c. Figure 3d also shows numerals which are unusually drawn. The vertical line of the "4" appears to be incomplete, and there is seldom a horizontal line at the bottom of a "4"; the closed loop on the "2" appears to have been deliberately drawn to induce confusion with a "9". Such ambiguities introduce some errors in performance, but they have nothing to do with color vision.

However, we have compared the geometry of the numerals on the new and old plates, and there is no difference; in that respect, the old plates have been faithfully reproduced.

DISCUSSION

The printing of the new Richmond Products plates is clearly less precise than that of the older plates. The separation of the dots has not been as carefully controlled, and the profusion of very small dots (used apparently as space fillers) has been eliminated. In addition, the general appearance of a given plate is often quite distinct from that of the corresponding older plate. The new printing often appears to be much lighter than the original plates. Overall, there appears to be less quality control.

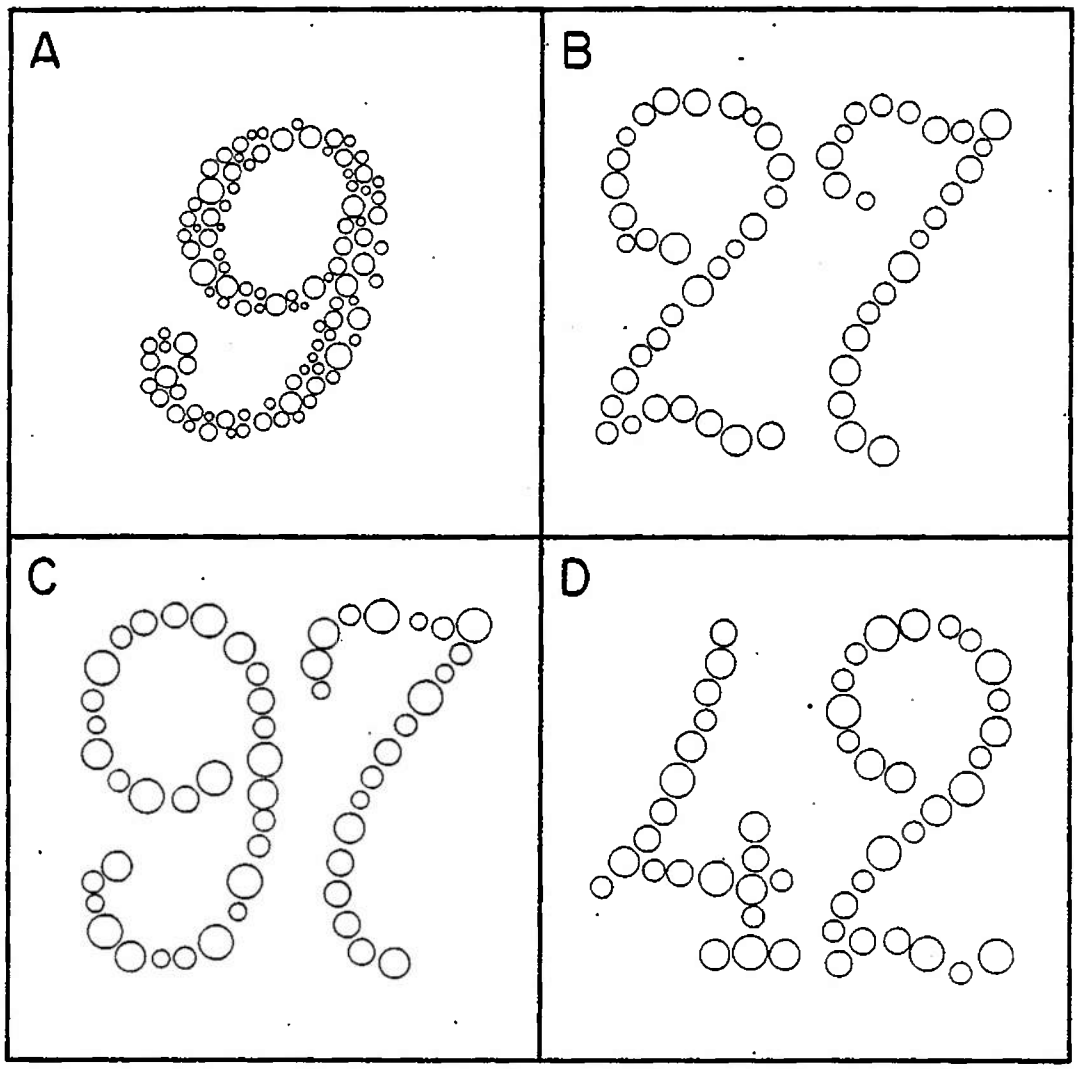


Figure 3. Tracings of the dots comprising numerals on the original set of plates showing (a) a clearly defined numberal, and (b-d) examples of numerals which are confusing apart from any color confusions.

Nevertheless, the spectroradiometric measurements show that, with the exception of only one color on one plate, the chromaticities and saturation purities have been reproduced with satisfactory accuracy. Only the luminances of the colors vary noticeably.

More important, the test results with 20 color normal individuals showed very little difference between the old and new sets. No color normal subject failed to pass the new plates. Those plates which were difficult for them to read in the new sets were also difficult to read in the old set. There is little basis in the present findings to question the adequacy of the new plates. They appear to be satisfactory. We do not know the failure rate which prompted questions about the new plates, but years of testing Naval recruits has led us to suspect that the incidence of color defects among men is actually slightly higher than the long accepted figure of about 8%, perhaps approaching 10%.

The obvious differences in the printings of the older and newer plates did not appreciably affect the scores of the individuals being tested. It is true that the lack of separation of the dots results in new and unintended colors as the two inks which overlap are mixed. But these random flecks of color spread throughout the plate simply introduce a small amount of background "noise" without skewing the general color in any particular direction and without appreciably affecting the subjects' scores.

We conclude that the new printing is satisfactory despite the obvious decrease in the precision of the printing, and that its continued use is justified.

We have two final comments. The Ishihara test for color blindness, a similar test to the one evaluated in this study, also classifies an individual who has made four errors as color normal. Okajima (1983) has suggested that the critical score be lowered to three errors. His statistics show that if this were done, fewer than one percent of the color vision defectives would be overlooked, and no normal subjects would fail. Interestingly, our data show that with the original set of plates, no color normal made more than three errors, supporting Okajima's position. But with the new plates, three color normals made four errors. They passed according to the accepted scoring standard, but they would, of course, have failed had they been required to make no more than three errors.

Finally, it is interesting to note that our subject who had had an operation for cataracts made five errors on two of the sets of plates, a failing score. Lakowski, et al. (1987) have recently presented data that error scores on color vision tests are always higher for glaucoma subjects. Perhaps the color vision of cataract patients warrants more study.

ACKNOWLEDGMENT

We thank HM1 Patrick Flaherty, USN for his many hours of technical assistance.

DISCLAIMER

This report is the result a request by CDR Uldis A. Delviks, MSC, USN, Chief of Ophthalmic and Optical Laboratory Instruments and Supplies, Defense Medical Standardization Board, Ft. Detrick, MD. The views expressed in this article are those of the authors and do not reflect the official policy of position of the Department of the Navy, Department of Defense, or the U.S. Government."

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A new printing of pseudoisochromatic plates was compared with the old printing in three ways to determine if individuals with normal color vision erroneously failed the new version. Spectroradiometric measurements of the colors were compared, 20 color normal subjects were tested, and the spatial arrangements of the dots comprising the plates were examined. There was no evidence that the new plates failed color normals, despite the fact that the quality control of the new printing was clearly less precise than that of the old plates.

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